Signatures of Special Nuclear Material: High-Energy g Rays Following Fission

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Since September 11, 2001, much effort has been devoted to the development of improved means for detection of the clandestine transport of special nuclear material (SNM, i.e. ^{235}U or ^{239}Pu). Here we describe a method for unequivocally identifying SNM in large seagoing containers. Our method is based on the fact that neutron-induced fission of ^{235}U or ^{239}Pu is followed by β decays of short-lived fission fragments during which large numbers of high-energy γ rays (> 3000 keV) are emitted. These γ rays have energies above those of natural background, are emitted with greater intensity than β-delayed neutrons, have higher probabilities of escaping hydrogenous cargo than neutrons, and their energy spectra and time dependencies provide a unique signature of SNM.

To demonstrate the main properties of high-energy delayed γ rays, we produced neutrons by bombarding a 1-inch thick Be target with 16-MeV deuterons from the 88-Inch Cyclotron. Neutrons were moderated using steel and polyethylene. We used a pneumatic transfer system to shuttle targets from the irradiation location inside the polyethylene moderator to a remote shielded counting station. We irradiated ^{235}U, ^{239}Pu, wood, polyethylene, aluminum, sandstone, and steel targets for 30 seconds (in a flux of 1.5×10^{6} thermal neutrons/cm^2-sec) and acquired ten 3-sec. γ-ray spectra, starting 3 sec. after the end of bombardment. We used a large germanium detector and a 30-cmx30-cmx10-cm plastic scintillator to detect γ rays and acquired data using ORTEC PC-based electronics and software.

The spectra observed from SNM targets are qualitatively different from those of any other materials. From non-SNM targets, we observed a small number of low-energy γ rays from the decays of long-lived isotopes such as ^{28}Al, ^{56}Mn, and ^{24}Na. However, from ^{239}Pu and ^{235}U targets, we observed a large number of high-energy γ rays produced by the decays of short-lived fission fragments. We concluded that a sensitive method to identify SNM is simply to integrate the total number of events in a wide energy interval. The integrated numbers of events from irradiated SNM decay with a short effective half-life of approximately 25 seconds, whereas those from all other materials tested showed much longer decay times. These two features – large numbers of high-energy γ rays decaying with a short effective half-life - provide a unique signature of SNM.

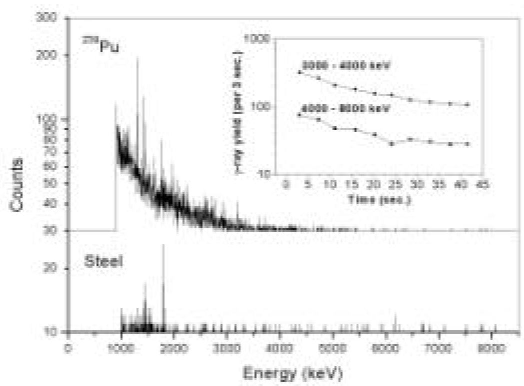

Fig. 1. γ-ray spectra observed in a germanium detector in 30 sec. of live time following neutron irradiation of 0.568 g of ^{239}Pu and of 115 g of steel. Inset: background-corrected decay curves for γ rays in the energy intervals 3000-4000 keV and 4000-8000 keV observed from the ^{239}Pu target.

Footnotes and References

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